



Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at <http://about.jstor.org/participate-jstor/individuals/early-journal-content>.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

THE VALUATION OF UNCONFORMITIES

ELIOT BLACKWELDER

University of Wisconsin

The utility of unconformities in geology has long been recognized, and the historical significance of such structures is becoming more and more clearly understood. In the early days of geologic science only the more clearly visible unconformities involving discordance of strata were identified as such. Later it was shown that an irregular eroded surface between parallel beds may imply much the same conditions and events as the more conspicuous unconformities, except that deformation of the older rocks is not involved. The distinction was clearly made by Irving, in his admirable paper on the correlation of unfossiliferous rocks; the breaks accentuated by discordance were called "true unconformities," while those in parallel strata were styled "erosion intervals."¹ It was felt that the very word "unconformity" involved the idea of angular discordance between the beds above and below, and hence that any interruption between parallel beds must go by another name. In spite of this, however, the scope of the term unconformity has been gradually extended so that we find Le Conte, writing in 1890, combining breaks between discordant beds and eroded surfaces in parallel strata as merely two varieties of unconformity.² This usage is the one now generally followed by geologists (although the phrase *erosion interval* is still current), and it is in this sense that the term will be employed in the ensuing pages.

We now have several types of unconformities clearly distinguished: (a) eroded surface separating parallel strata; (b) contact between rocks of wholly unlike origin (for example, sandstone resting upon granite); and (c) angular discordance of beds with or without difference in lithologic character.³

¹ R. D. Irving, *U. S. Geol. Surv., Ann. Rep.*, VII, 1886, pp. 392, 393.

² Jos. Le Conte, *Elements of Geology*, 3d ed., 1893, p. 180.

³ The phrase "eruptive unconformity," recently used to describe broad intrusive contacts of granite with older schists, is here excluded, on the ground that even if such structures are unconformities in any sense, they differ from erosional unconformities so fundamentally that the two cannot well be discussed together.

The criteria for identifying unconformities under varying conditions have been so carefully studied and systematized in recent years that they are generally well understood. The average student of geology knows that unconformities may be identified by means of basal conglomerates, by weathered zones on the underlying formations, by the truncation of dikes, faults, and other structures, by the general field-relations of the outcrops, by actually observed discordances and irregularities at contacts, and by still other means.¹

At first the events signified by an unconformity were somewhat indefinitely realized. That the structure indicated an episode of erosion and the absence of strata which existed in other places, and that in some cases more or less disturbance had taken place in the intervening time, was clearly apprehended. Geologists are now generally agreed that an unconformity implies: (a) cessation of deposition (usually involving emergence, and often accompanied by deformation of the rocks); (b) denudation (usually by subaerial processes); (c) resumption of deposition (usually attending submergence, but often by terrestrial processes). It is also clearly understood that an unconformity represents a "lost interval," or lapse of time which is otherwise unrecorded at that place. The interpretation of this lost interval is the chief subject of the present paper, and is the one which most requires analysis and a definition of factors.

Writers of papers on stratigraphy not uncommonly state that a given unconformity is a great unconformity, or that another is a slight one; that it represents a vast lapse of time, or a minor episode only. The reader, however, cannot always know just what is meant by these expressions. From the context of such papers one may infer that the unconformity is considered great by one writer because of one feature, and by another because of a very different feature. A few examples will make this clear.

Regarding the unconformity at the base of the Keweenawan series, Van Hise says, ". . . in areas in which the unconformity . . . is *not great*, there is such a likeness in strike and dip of the two series as to suggest, at first, that the two are conformable."² Here apparently

¹ The criteria are exhaustively treated by Van Hise in a paper on the "Principles of Pre-Cambrian Geology," *U. S. Geol. Surv., 16th Annual Report*, Pt. I, 1896.

² "A Historical Sketch of the Lake Superior Region to Cambrian Time," *Jour. of Geol.*, I (1893), 127.

greatness is measured by the degree of discordance; the great unconformity being the one in which the lower series has been much more deformed than the upper, while the slight unconformity separates beds which have similar structure.

Walcott describes the break separating the Cambrian from the Belt series in Montana as a "slight unconformity"¹ because the dividing line is rendered very inconspicuous by the parallelism of the strata above and below. But on another page he refers to the same interruption as a "great stratigraphic unconformity,"² because it represents the loss of 3,000-4,000 feet of Algonkian strata by erosion. Here is an implication that an unconformity may be considered great if there is a large "lost interval," even if it is inconspicuous because the lower and upper beds are not discordant.

Referring to the unconformity between the horizontal beds of Ordovician and Carboniferous (Pennsylvanian) strata in eastern China, the present writer says:

The absence of Silurian, Devonian and Lower Carboniferous series from Shantung indicates that the interval of erosion *may have* included all of those periods, and thus be worthy of rank as an unconformity of the first magnitude. It is possible, however, that sedimentation continued long after Ordovician time, and that the resulting rocks were subsequently removed by erosion, in all localities thus far examined. . . .³

In this case lapse of time is made the sole criterion of greatness, and is discriminated from stratigraphic break or thickness of strata missing.

To summarize these different usages, then, an unconformity is sometimes called great (*a*) because there is prominent discordance of structure, (*b*) because a great thickness of strata is lacking, or (*c*) because the making of the unconformity involved a long lapse of time. It is true that these factors may all apply to any one unconformity, but they do not necessarily agree with each other. Great stratigraphic break is usually regarded as implying great lapse of time, and hence the two ideas are often combined in discussions and the expressions are used as if they were equivalent. In the study

¹ C. D. Walcott, "Pre-Cambrian Fossiliferous Formations," *Bull. G. S. A.*, X, 211.

² *Loc. cit.*, 204.

³ Bailey Willis, Eliot Blackwelder, and R. H. Sargent, *Research in China*, I, Pt. I (1907), pp. 48-49.

of ancient pre-Cambrian terranes, or others which are devoid of fossils, it may not be practicable to determine how great a thickness of the record is lost, and, much less, the time through which the land conditions endured. The term "great," then, has value as indicating the geologist's opinion that the discordance is pronounced and that it doubtless implies great loss of record. In this sense it is a convenient word and has been of much service. Nevertheless, for the sake of clearness, the three factors should be carefully discriminated wherever that is feasible, even if their value cannot be definitely appraised.

To show that the stratigraphic hiatus¹ is not necessarily a measure of the lapse of time during which the unconformity was being made, I may cite Le Conte, who says: "Every case of unconformity represents a gap in the geologic record at that place. . . . The loss of record may be partly by erosion, but mostly because not written at that place."² Unquestionably the stratigraphic break represents a lapse of time not now recorded in that place. But the region may have continued to be the scene of deposition during a part of that time, and the strata thus formed, and carrying the record, have been removed in the ensuing period of erosion.

By way of illustration we may take two unconformities which are somewhat similar as regards the length of the unrecorded interval, but are very different in time-value. At Rome, Georgia, Tertiary strata rest upon folded Cambrian rocks. In the Bear Lodge Mountains, northwest of the Black Hills of North Dakota, Tertiary beds may also be found upon Cambrian strata at certain points. The lost interval in each section is represented by all the strata from late Cambrian to Tertiary. In the first case, however, the deposition of sediments continued with brief interruptions from Cambrian to at least Pennsylvanian times, and then apparently was supplanted by erosion from Permian to late Tertiary times. In the second case sedimentation persisted until the end of the Cretaceous period, and gave way to erosion only during the Eocene period. It is plain, therefore, that although the stratigraphic break is nearly identical in

¹ By this term is meant the gap in the strata; i. e., where Devonian lies on Cambrian, the *stratigraphic hiatus* is equivalent to the Ordovician and Silurian systems.

² Jos. Le Conte, *Elements of Geology*, 3d ed. (1893), p. 181.

the two sections, the time-value is very different, being equivalent to five to seven periods of geologic history in the Georgian region, but to only one period, or a fraction of a period, in Wyoming.

The same thing may be brought out by examining one of these two unconformities at different points. Fig. 1 represents diagrammatically the pre-Oligocene unconformity of the Black Hills region. In a section taken at (A) horizontal Oligocene silts (solid black) rest on folded Algonkian slates and granite; at (B) upon tilted Permian shales, and at (C) upon horizontal late Cretaceous sandstone and shale. Judged from the standpoint of structural discordance, the unconformity is very great at (A), moderate at (B), and nil at (C). Regarded from the basis of stratigraphic hiatus, it is greatest at (A), less at (B), and least, although still noteworthy, at (C). But the time-value is probably much the same at all three points. The



Fig. 1.—Pre-Oligocene unconformity in the Black Hills. The section is diagrammatic and generalized.

history of the region appears to be roughly this: Sedimentation was continuous from the Cambrian to the close of the Cretaceous period save for temporary episodes of erosion in mid-Paleozoic, and Jurassic times. No deformation attended these early changes, and the final result of the deposition was a thick blanket of strata lying horizontally across the region of the Great Plains. At the close of the Cretaceous period a low dome was bulged up, and during the Eocene the top of this was beveled off so that the pre-Cambrian rocks were exposed within encircling rims of younger beds. To this epoch of erosion the entire unconformity under discussion is due; and it would seem therefore that the time-value of the break is to be measured in this way rather than by the time-equivalent of the strata which are missing in any one section.

It appears, then, that unconformities seen in isolated sections may be prominent or obscure structurally, that they may represent a large or a small gap in the sedimentary column, and that they may

indicate a period of erosion of long or short duration, not to be estimated by the "lost record."

At this point it will be advisable to consider how these three factors may be determined with reference to a given unconformity. The degree of discordance may often be observed directly in sections, or may be inferred from observations of strike and dip. The stratigraphic hiatus may be discovered by correlating the beds above and below with a standard section of reference (supposing that such a section has been established), and thus determining what formations are lacking. These are matters of common knowledge and need not be dwelt upon here. The time-value, however, is not so easily ascertained, since observations on one section, or even on several adjacent sections, are not sufficient to bring out the facts. Let us start with the generally understood principle, ably presented in recent years by Chamberlin and Salisbury,¹ that *all unconformities are presumably limited in extent*; when traced in any direction they are eventually lost in a conformable sequence of strata. Thus the present eroded surface of North America—a future unconformity—merges into the continuous sediments of the seas about its borders. But some parts of this land mass have been out of water much longer than others, and so the unconformity which is to be will have a different time-value in different places. For example, if the sea-level should rise steadily the sea would encroach upon the land. With it would come the sedimentation for which it furnishes the conditions. In the southern Great Plains these modern sediments would lie first upon the Quaternary beds of the Gulf border. As the sea has been only recently excluded from this strip, the time-value of the intervening unconformity would be small—probably a fraction of the Quaternary period. Further slow advance of the sea would allow somewhat later deposits to be laid over a surface which seems to have been land since Miocene times. Continued encroachment would eventually allow deposits of still later age to be spread upon land which has been eroded presumably since the Eocene epoch. Here evidently the time-value is greater than in either the first or the second locality. The events and time-intervals are expressed graphically in the accompanying diagram (Fig. 2). This particular unconformity, it will be observed, began

¹ T. C. Chamberlin and R. D. Salisbury, *Geology* (1906), II, 222-24.

to be developed at *C* in Eocene times and ceased to be made at *C* in the fifth post-present epoch. Its time-value reaches its maximum at that place, covering ten to eleven epochs, while at the present Gulf coast (*A*) its value decreases to zero. This illustrates in a very simple way the principle that most unconformities gradually increase or decrease in time-value from place to place; that there is a waxing and a waning phase corresponding to recession and incursion of the sea or to the shifting of the sites of continental deposition. If the recession or invasion is very rapid, the lower or upper line of our diagram will approach the horizontal, but such changes will be matters of degree, not of kind.

Actually, however, the relations are rarely as simple as this, nor

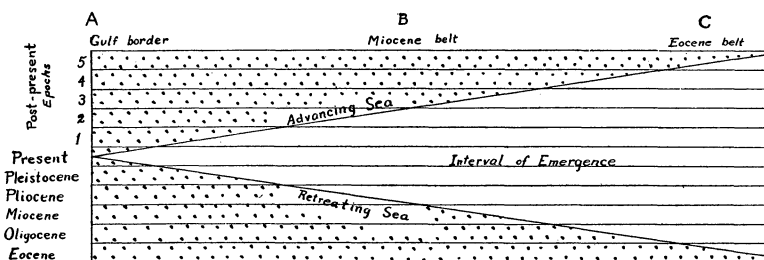


Fig. 2.—Diagram of a simple unconformity. The dotted area represents sedimentation, the blank space erosion. The horizontal lines denote equal time.

are the advances and retreats as regular. In the case just given it will also be observed that the stratigraphic hiatus varies almost directly with the time-value, a phenomenon which is somewhat common among unconformities, but is by no means the rule.

A case of average complexity may be formulated by imagining the middle Atlantic seaboard of the United States to be gradually submerged (Fig. 3). In an early stage of the encroachment of the sea modern sediments would be laid down upon Pleistocene sand and clay in the Chesapeake region (*A*); farther west younger beds would rest upon Miocene (*B*)—much as in the Texas example. Still later beds, however, would overspread the Piedmont belt with its ancient crystalline rocks. The discordance would suddenly change from slight to very great (*C*); and likewise the hiatus, which was equivalent to Tertiary-Modern on the coastal plain, would quickly expand to

a gap embracing perhaps Algonkian-Modern. Assuming as correct the current view that the Piedmont at this point was submerged in the Ordovician¹ period, but not later, we find that the time-value

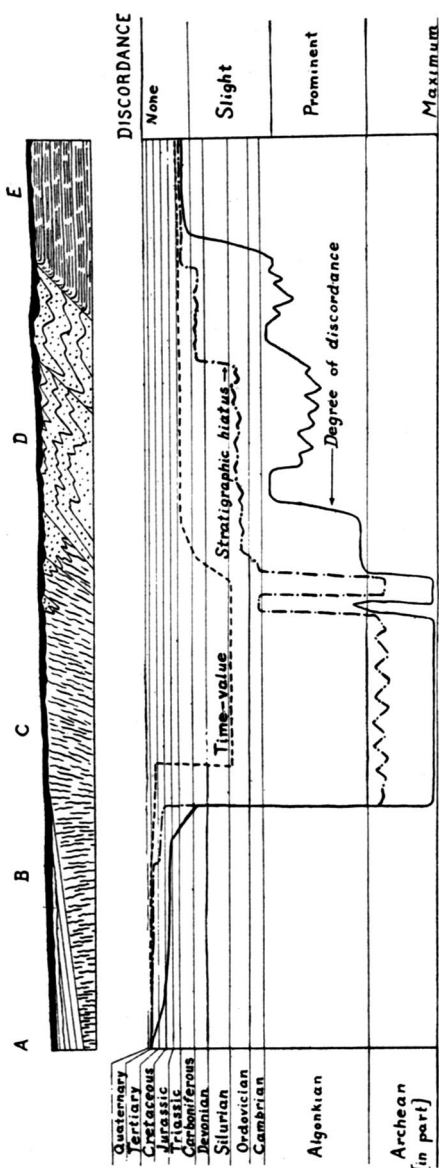


Fig. 3.—Hypothetical modern unconformity on the middle Atlantic slope. Positions on the diagram of curves coincide with similar positions on the generalized section.

has also changed from Miocene - Modern to Ordovician-Modern, a great and relatively abrupt change, but not so great as that observed in the hiatus. Farther westward (D) submergence would cause modern sediments to be laid upon the truncated edges of the Paleozoic strata in the Appalachian Valley and Mountains. The discordance here is less, although still great, and the stratigraphic hiatus has decreased to perhaps Ordovician-Modern. The region is believed to have been eroded ever since the Permian period, and so the time-value is Permian-Modern. Now supposing the submergence to lap over upon the Allegheny plateau (E), angular discordance is quickly

¹ N. H. Darton, *Am. Jour. Sci.*, 3d series, Vol. XLIV (1892), pp. 50-52.

reduced to insignificance (although the eroded surface itself would be very uneven). Stratigraphic hiatus decreases to a value of Pennsylvanian-Modern. Time-value, however, suffers no corresponding change from the previous locality.

It appears then that the three factors, discordance, hiatus, and time-value, may vary suddenly and largely, but that they do not necessarily vary in the same degree, or even in the same phase. Time-value may decrease while hiatus increases. Discordance may occasionally become more pronounced as the lost record becomes smaller.

These considerations lead to the conception that unconformities are constantly fluctuating features of the stratigraphic record. It is also plain that the time-value of an unconformity can be determined only through the study of the geologic history of a considerable region, while discordance and hiatus can often be ascertained from individual sections.

The hypothetical case just considered, of an unconformity in eastern United States, fails, however, to give a complete picture of that unconformity since the assumed case represents only one withdrawal and advance of the sea. As a matter of fact we are to think of such a region as the Piedmont belt, or, let us say for the present example, the Canadian shield of ancient rocks, as being a land nucleus of varying dimensions, now expanding by withdrawal of the epicontinental sea, until it includes a continent, and then contracting to a mere island, perhaps smaller than Greenland, as the sea overspreads its shelving surface. These advances and retreats have taken place, not once, but many times, and the result is quite as many unconformities, *all of which blend landwards into one far greater unconformity* which records the continuous land condition of the central nucleus.

This is illustrated by Fig. 4, which shows an interpretation¹ of the submergences and emergences of a part of central United States since pre-Cambrian times, with the corresponding sedimentary series and unconformities. Vertical spaces represent periods of time, while on the horizontal line are scaled off certain broad provinces stretch-

¹ In this and other examples used in the present discussion the facts are but imperfectly known, nor does the writer profess to have made an exhaustive study of even those which are available. His interpretation of the history is not in any way essential, but will serve the purpose of illustrating the general principles.

ing from Labrador on the northeast (to the right) to southern Texas on the southwest (to the left). On the right, one sees that Labrador has been eroded from some time before the Cambrian down to the glacial period; and even then the deposition was accomplished by glaciers—a terrestrial agency. The unconformity there represents

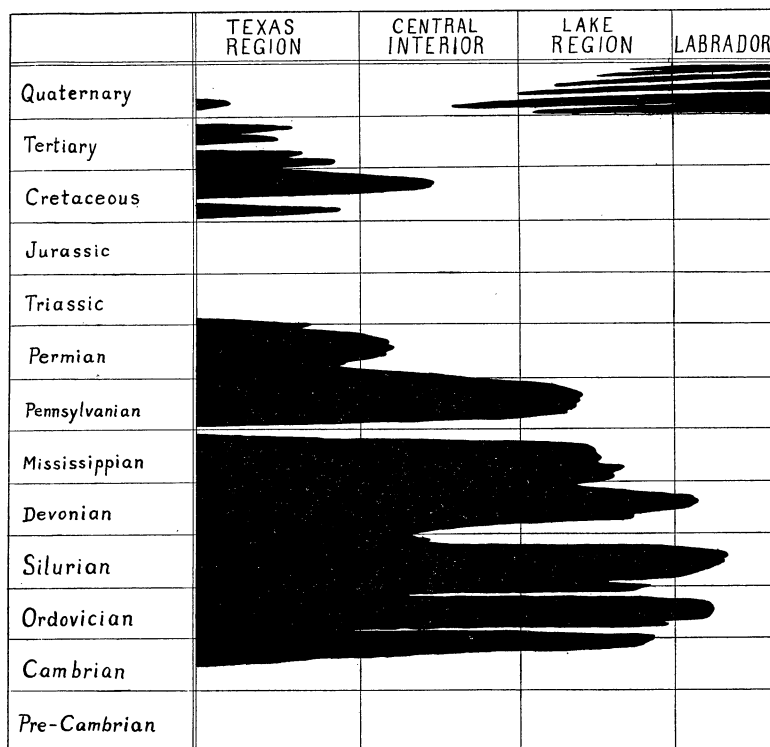


Fig. 4.—Diagram of an unconformity with lateral extensions and restrictions. The extent and duration of the principal periods and areas of sedimentation, with their corresponding rock systems, are shown in solid black. The white, on the other hand, denotes the time and extent of erosional conditions and corresponding unconformities.

a vast and presumably uninterrupted lapse of time. When traced southwestward, however, this great denudation-interval branches into many minor intervals which are intercalated between periods of sedimentation—the times during which the so-called sedimentary record was produced. The minor unconformities dovetail in with the sedimentary series, especially around the borders of the continent.

Traced toward the old land nucleus, the many little unconformities merge into a few, and finally into one all-inclusive unconformity. Traced seaward, the sedimentary wedges of the record expand into continuous piles of marine strata; for over much of the oceanic abysses sedimentation has probably been uninterrupted since the Archean period or before.

Our more familiar unconformities are to be thought of, then, as temporary expansions or wedge-shaped extensions of greater unconformities, and we must not be surprised if, when traced in one direction, they dwindle to nothing,¹ or if in another direction they expand so as to swallow up the entire sedimentary record.

SUMMARY

In the preceding discussion, the writer seeks to show that the words "great" and "slight" as applied to unconformities are often ambiguous and in need of definition; that, where these things can be determined, it is important to know whether the *structural discordance*, or the *stratigraphic hiatus*, or the *duration of erosion*, is the thing that is great or small.

It appears that the stratigraphic hiatus or lost record is not necessarily a measure of the time which elapsed while the unconformity was being produced. The two may be nearly equal, but on the other hand the lost time may be much less than the lost record. It cannot well be greater.

Also, all three factors change from place to place—the discordance and hiatus often suddenly and capriciously, the time-value usually more gradually.

Many, if not most, unconformities are merely lateral extensions of much more persistent unconformities. The main unconformity denotes a very long duration of terrestrial erosive conditions, while the projecting wedges record the backward and forward migrations of belts of sedimentation around the borders of that land.

The entire geologic record then is not to be conceived of as a pile of strata, but as a dovetailed column of wedges, the unconformities and rock systems being combined in varying proportions. The former predominate in some places and periods, while the latter prevail in others.

¹ This conception is admirably explained by Chamberlin and Salisbury in *Geology*, II, chaps. iv, v.